

UPPER TRISHULI-1 HEP (216MW)

Client	Nepal Water and Energy Development Company Private Limited
Owner's Engineer	Tractebel Engineering GmbH / Jade Consult

REVIEW NOTE

Contractor	Doosan Heavy Industries & Construction Co., Ltd.		
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A: Approved AC: Approved with Comments RR: Returned for Resubmission

The Designer has submitted rock parameters that should be used for the design of the tunnels in the UT-1 Project. The document was produced after the Internet Conference on 13. October 2021 and other previous communication. The parameters were eventually presented as shown in the table below. The following comments apply:

- The rock parameters as shown in the table below are acceptable.** The UCS_{rm} is only for information for the designer, but it is, of course, not an input for calculations. (It is irrelevant in the design calculations.) Note that the Q-value is also entirely independent of UCS. The Mohr-Coulomb Criterion can be written in principal stresses as

$$\sigma_1 = \frac{2ccos\phi}{1 - \sin\phi} + \sigma_3 \frac{1 + \sin\phi}{1 - \sin\phi}$$

where

$$\sigma_1 = \frac{2ccos\phi}{1 - \sin\phi} = UCS$$

and

$$\sigma_3 \frac{1 + \sin\phi}{1 - \sin\phi} = mobilized\ strength$$

The corresponding cohesion and friction angle shall be used to determine UCS_{rm} . The table needs to be revised with the correct UCS_{rm} as shown in **red** numbers.

Table: Acceptable rock parameters as suggested by POWER CHINA. The UCS_{rm} was corrected by using the Mohr-Coulomb Criterion using the given cohesion and friction angle.

ROCK TYPE	ROCK CLASS	Q	γ (kN/m ³)	μ	Em (GPa)	c (MPa)	ϕ (°)	UCS _{rm} (MPa)	INTACT UCS _i (MPa)
SCHIST/ GNEISS	I	> 40	27.0	0.20	30.0	5.0	50	27.5	60
	II	10--40	27.0	0.25	20.5	2.5	48	13.0	60
	IIIa	7--10	26.5	0.25	10.0	1.0	45	4.8	60
	IIIb	4--7	26.5	0.28	5.0	0.8	42	3.6	60
	IV	1--4	26.0	0.30	2.3	0.5	35	1.9	60
	V	< 1	24.0	0.35	0.9	0.2	25	0.6	60

- Residual strength parameters c_r and ϕ_r shall be provided.
- It is not necessary to use the Hoek-Brown Criterion to determine cohesive and frictional strength of the rock mass. The respective cohesive and frictional strength depends in calculations with this criterion on the stress environment and is hence dependent on overburden thickness, excavation size and shape, etc.
- It is fully sufficient to use the Mohr-Coulomb Criterion in the design of underground structures (tunnels) in this project.

The Designer is reminded that the contract states:

- Shotcrete shall be divided into general shotcrete and high strength shotcrete. The performance and quality shall be guaranteed for the purpose of shotcrete installation. Design criterion strength of 28 day aged shotcrete shall be above 21MPa in the general shotcrete and above 35MPa in the high strength shotcrete. 1 day aged shotcrete shall have strength above 10MPa.

This means that the 28-days strength shall be above 21 MPa. This contractual clause does not mean that it must be exactly 21 MPa, but it means more than 21 MPa (for example 25 MPa or 30 MPa). Generally, in underground works shotcrete with a strength of 30 MPa is used, worldwide, as it is economically most efficient.

Shotcrete with a strength of 21 MPa requires thicker shotcrete lining to satisfy the design criteria than 30 MPa shotcrete. A 100 mm shotcrete lining for a 30 MPa shotcrete requires approximately 150 mm lining for a 21 MPa shotcrete. **This results in an increase**

- of shotcrete (= cement and aggregates, > 1,25 m³ per meter for a 5 m dia. tunnel)
- of the tunnel diameter (here 0.1 m)
- of the explosives required
- of rock material to be mucked (> 1,25 m³ solid material per meter for a 5 m dia. tunnel)
- of the construction time

For a 300 m long tunnel this adds up to 375 m³ of additional shotcrete (= 50 mixer trucks), only.

This simple example highlights that it must not be necessarily cost- and time-efficient when using 21 MPa shotcrete instead as generally used 30 MPa shotcrete. Furthermore, it is noted, the requirement of a 1-day strength of 10 MPa will not be easily achieved with a 21 MPa shotcrete.

The designer must consider all consequences when deciding on shotcrete strength.

The Designer is reminded that maximum overburden thickness of the tunnel shall be used in stability calculations. The reason is to cover the possibility that any rock class may prevail at greatest overburden.

The Designer is reminded to reconsider his suggestion to omit systematic bolting in Class II. The calculation may show only small amounts of displacements for this rock class (say few millimetres). Such displacements in a blocky rock mass of good quality occur always on pre-existing discontinuities (joints, foliation). These are relative displacements between individual blocks leading – even at small displacements - to a drop of the joint strength from peak strength to residual strength. This can create instable blocks that fall from the tunnel roof when the tunnel is advancing. For this reason, in tunnelling there is always systematic rock bolting in Class II – at least in the tunnel roof - to create acceptably safe conditions in the tunnel.

DISCLAIMER

Any approval will not release the Contractor from any of his obligations under the Contract.

Dr. Ulrich Glawe



(Signature)